

**SPECTROSCOPIC DETERMINATION OF THE PHYSICAL CONDITIONS
IN HOT OPTICALLY THIN SOURCES**

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**Spectroscopic Determination of the Physical Conditions in Hot,
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October 21, 2003

This annual report covers the period from Oct 1, 2002 to Sep 30, 2003.

APEC/APED. The Astrophysics Plasma Emission Code and Database (APEC/APED), developed in part under this grant, have been upgraded to ATOMDB Version 1.3.1: <http://asc.harvard.edu/atomdb>, and are now beginning to find widespread applications to X-ray spectral data from Chandra and XMM-Newton (37 citations in published work, according to the ADS, plus numerous other conference and prepublication papers). ATOMDB is now linked through the Plasma Gate website: <http://plasma-gate.weizmann.ac.il/DBfAPP.html>.

The major difference from Version 1.3.0 is that the new models now extend to 50 keV rather than stopping at 10 keV. This means that ATOMDB can be used with redshifted observations. There are minor differences in emissivities due to radiative recombination and cascades.

We are continuing to make progress in improving the spectral models between 30 and 90 Å, by the addition of HULLAC calculations and NIST wavelengths for L-shell ions of Ne, Mg, Si, S, Ar, and Ca. See: <http://physics.nist.gov/PhysRefData/Chandra>.

We are working to document APEC and find beta-testers, as part of our efforts to make the code public. We are also working with users of the public versions of APEC, ATOMDB, and various CXC tools to access the database files. These interactions are critical to ensuring quality control, and provide additional useful tests. Eugene Churazov and Bill Forman raised questions about the Nickel calculations, based on differences between APEC and MEKAL model fits to cluster spectra. We found a line inadvertently left out of APED as a result, and have now also worked through critical evaluations of nickel and iron models at cluster temperatures.

We have also compared our calculations for cooling curves using APEC with those published by Harry Warren and Amy Winebarger. This comparison exposed a units conversion problem in APEC (the first actual code bug discovered in over a year, as distinct from database errors). Finally, we have worked with Leon Golub and Nariaki Nitta to help make APEC more ac-

cessible to the solar community. Although the solar community is currently invested in CHIANTI for UV spectral modeling, it is now being recognized that APEC includes far more X-ray transitions and is better for modeling Yohkoh data, and for simulating spectra for new solar X-ray instrumentation development.

The Emission Line Project. Stellar coronae are being used to benchmark the atomic data in APED as part of the Emission Line Project. The models appear to be in good agreement with the observations for most of the strong lines; however, we have identified significant discrepancies in the 3s/3d line ratios not only for Fe XVII, but also for Fe XVIII and XIX. The Fe XVII problem has been known from solar observations, and is currently being tested under EBIT laboratory conditions by two groups. The Fe XVIII problem is substantially worse, but perhaps will shed light on the relevant underlying theoretical issues. Ming-Feng Gu has recently published new calculations, which we are comparing with APEC and with the observations. His calculations appear to improve the emissivities of lines affected by cascades, but other problems remain. These results have been reported at several conferences and are being written up for publication (P. Desai et al. 2003, in preparation).

We have also shown that careful modeling can allow us to estimate of the effects of line blends on diagnostic ratios. Jan-Uwe Ness led this project during a visit to the CfA sponsored by this LTSA grant. We focused on the very crowded region near the Ne IX spectral lines in Capella. Our paper (Ness et al. 2003) shows also the importance of including laboratory wavelengths, since otherwise, line identification of blending lines would not even be possible (and in fact, remains a problem for the Mg XI He-like triplet lines).

Collaborations to improve spectral modeling. We continue to collaborate widely with atomic physicists in order to find the best atomic data, and to solicit calculations and measurements that are needed. Several visitors to the Institute for Atomic and Molecular Physics here at the CfA are working with us on various projects,

We have also initiated several new collaborations to help compile data, including a collaboration with Cara Rokowski (new PhD from Rutgers now at the CfA) on inner shell processes of particular importance to non-equilibrium ionization. Yair Krongold is using APED to generate opacities for modeling X-ray photoionized plasmas. (In fact, this usage uncovered an error in the

database in rates not being used by APEC, and so provided another valuable test.) His new code PHASE is being developed for public use, and demonstrates the value of a stand-alone public database with different application codes. We are now looking into emission modeling in photoionized plasma so that self-consistent plasma models can be generated.

Management. Dr. John Raymond, Dr. Duane Liedahl, Dr. Randall Smith, and Dr. Ronnie Hoogerwerf continue to work closely as collaborators on this project. We are also fortunate to have Dr. Yair Krongold at the CfA as a visitor, partially supported by this LTSA grant.

Publications and Presentations during the Reporting Period

- Toward a Self-Consistent Model of the Ionized Absorber in NGC 3783, Krongold, Y., Nicastro, F., Brickhouse, N. S., Elvis, M., Liedahl, D. A., & Mathur, S. 2003, *Ap. J.*, in press
- Modeling the Ne IX Triplet Spectral Region of Capella with the Chandra and XMM-Newton Gratings, Ness, J.-U., Brickhouse, N. S., Drake, J. J., & Huenemoerder, D. P. 2003, *Ap. J.*, in press
- The Structure of Stellar Coronae in Active Binary Systems, Sanz-Forcada, J., Brickhouse, N. S., & Dupree, A. K. 2003, *Ap. J. S.*, 145, 147
- Astrophysics and Spectroscopy with Microcalorimeters on an EBIT, Takacs, E. et al. (15 authors) 2003, in *Nuclear Instrumentation and Materials B*, 205, 144
- Quantitative Analysis of Coronal X-ray Spectra at High Resolution, Brickhouse, N. S. 2003, in *X-ray and Gamma-ray Telescopes and Instruments for Astronomy*, ed. J. E. Truemper & H. D. Tananbaum, Proceedings of the SPIE, Vol. 4851, 69
- Structures of Binary Star Coronae, Brickhouse, N. S. 2003, (Invited), IAU Symposium 219, Stars as Suns: Activity, Evolution and Planets, in press
- Using Chandra/LETG Spectra to Probe Stellar Coronae, Hussain, G. A., Brickhouse, N. S., Dupree, A. K., van Ballegooijen, A. A., Collier Cameron, A., Donati, J.-F., Jardine, M., & Wood, K. 2003, IAU Symposium 219, Stars as Suns: Activity, Evolution and Planets, in press

- Plasma Studies at X-ray Spectral Resolution 1000, Brickhouse, N. S. 2003, (Invited), IAU Joint Discussion 20, *Frontiers of High Resolution Spectroscopy*, in press
- Modeling with APEC, Brickhouse, N. S., & Smith, R. K. 2003, (Invited), IAU Joint Discussion 17, *Atomic Data for X-ray Astronomy*, in press
- The Astrophysical Plasma Emission Database: Progress and Plans, R. K. Smith, N. S. Brickhouse, & D. A. Liedahl, IAU 2003, *Proceedings of Joint Discussion 17, Atomic Data for X-ray Astronomy*, in press
- Microcalorimeter Measurements of AN Electron Beam Ion Trap, Silver, E., Takacs, E., Laming, J. M., Gillaspay, J. D., Schnopper, H., Brickhouse, N., Barbera, M., Mantraga, M., Ratliff, L. P., & Tawara, H. 2003, IAU Joint Discussion 17, *Atomic Data for X-ray Astronomy*, in press
- Learning Physics from the Sun: Radiative Processes, Brickhouse, N. S., (Invited) Parker Lecture, AAS Solar Physics Division Meeting, June 2003, Columbia, MD
- Probing the Physics of Stellar Coronae with High Resolution X-ray Spectroscopy, Brickhouse, N. S., presented at First Constellation-X Workshop on X-ray Spectroscopy, May 2003, New York, NY
- X-Ray Spectral Modeling with APEC, Brickhouse, N. S., presented at ITAMP Workshop on EUV and X-Ray Emission from Comets, Planets, and Heliospheric Gas, January 2003, Cambridge, MA
- Quantitative Analysis of High Resolution X-ray Spectra, SAO High Energy Astrophysics Division Seminar, October 2002, Cambridge, MA
- The Chandra LETG Spectrum of Lambda Andromedae, Brickhouse, N. S., Dupree, A. K., & Hoogerwerf, R. 2003, AAS HEAD Meeting, 35, 1204
- X-ray Doppler Imaging of Rapidly Rotating Stellar Coronae, Hoogerwerf, R., Brickhouse, N. S., & Dupree, A. K. 2003, AAS HEAD Meeting, 35, 1205
- An Assessment of the Fe XVIII and Fe XIX Line Ratios from the Chandra Grating Observations of Capella, Desai, P., Brickhouse, N. S., Drake, J. J., Dupree, A. K., Edgar, R., Hoogerwerf, R., Kashyap, V., Smith, R. K., Wargelin, B. J., Huenemoerder, D. P., & Liedahl, D. A. 2003, AAS HEAD Meeting, 35, 1206
- Modelling the NeIX Triplet with Chandra Using HEG, MEG, and LETGS, Ness, J.-U., Brickhouse, N. S., Drake, J. J., & Huenemoerder, D. P. 2002, *High Resolution X-ray Spectroscopy with XMM-Newton and*

Chandra, Proceedings of the Workshop held at Mullard Space Science Laboratory, ed. G. Branduardi-Raymont, E26

Conferences Attended during the Reporting Period by the PI

Dr. Brickhouse:

AAS Meeting, January 2003, Seattle, WA

AAS High Energy Astrophysics Division Meeting, March 2003, Mt. Tremblant, Canada

AAS Solar Physics Division Meeting, June 2003, Columbia, MD

First Constellation-X Workshop on X-ray Spectroscopy, May 2003, New York, NY

International Astronomical Union 25th Meeting, July 2003, Sydney, Australia

ITAMP Workshop on EUV and X-Ray Emission from Comets, Planets, and Heliospheric Gas, January 2003, Cambridge, MA

Conferences Attendance during the Reporting Period Fully or Partially Supported by this Grant

Dr. Hoogerwerf:

AAS High Energy Astrophysics Division Meeting, March 2003, Mt. Tremblant, Canada

Dr. Krongold:

First Constellation-X Workshop on X-ray Spectroscopy, May 2003, New York, NY